

A SAME NET SPACING VIOLATION CHECKER

BACKGROUND OF THE INVENTION

Field of the Invention

5 The present invention generally relates to methods and systems for checking spacing of wiring in a semiconductor structure and more particularly to a method and system for checking the spacing of wiring within a single net.

Description of the Related Art

10 Conventional design rules require wires of the same net within a semiconductor structure to be spaced a specified minimum distance apart. Older designs satisfied the minimum spacing requirements fairly easily through simplified grid designs which automatically guaranteed that minimum spacing design rules were met. However, with advancing technologies wider wires are more prevalent. Such wide wires have larger spacing requirements than the older narrower wires. Therefore, a simple gridded solution is no longer effective with
15 today's current wide wires.

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5 The process of forming minimum spacing rectangles comprises forming the minimum spacing rectangles to have sides which are a minimum spacing design constraint distance from sides of respective ones of the conductor rectangles.

10 The conductors are preferably within a single net. If the circuit comprises a plurality of nets the process further includes checking for shorts between different ones of the nets.

The invention can also include dividing the possible error rectangle into at least two possible error rectangle if the possible error rectangle is partially covered by a third conductor of the conductors.

15 The invention is superior to conventional systems because the invention allows same net spacing errors to be recognized during physical design prior to Design Rules Check. The software supporting the invention performs orders of magnitude faster than the Design Rules Check solution. As such, the invention dramatically decreases the turn-around time of physical design, providing a fast solution which is available prior to final layout release.

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Figure 10 is a revised schematic illustration of Figure 8 illustrating additional metal shapes which do not remove the spacing violation;

Figure 11 is a schematic diagram of a computer system and software program for performing the invention; and

Figure 12 is a flowchart illustrating an embodiment of the invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS OF THE INVENTION

Referring now to the drawings, and more particularly to Figure 1, a rectangle representing a conductor shape M1, such as a metal wiring, and a spacing rectangle S1, which defines a minimum space "d" according to design rules around the metal shape M1 are illustrated. The metal shape is a part of a larger overall conductive net within a structure, such as a semiconductor. The metal shape comprises circuit components which operate by transmission of signals through the net.

A first stage of the invention involves a plane sweep of all the net's components (e.g., net parts) such as vias, wires segments, pins or powers. The first rectangle M1 represents the shape of the net part and the second rectangle S1 represents the minimum spacing requirement surrounding the net part M1. The size of the second minimum spacing rectangle S1 is determined by the design

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removes the possible spacing error rectangle from the possible error list.

For example, as illustrated in Figure 5, metal shape M3 completely covers possible error P1. Therefore, since no actual space exists between metal shapes M1 and M2, the possible error rectangle P1 illustrated in Figure 5 is not a true spacing error and is properly removed from the possible error list.

Figure 6 illustrates a metal shape M3 which only partially covers the possible spacing error in P1. In such a situation, the invention creates multiple possible spacing error rectangles (e.g. P2, P3) from the original possible spacing error P1, as illustrated in Figure 7. The possible spacing error P1 is removed from the possible error list and the newly created possible spacing errors (e.g. P2, P3) are added to the possible error list. Each of the newly created possible spacing errors (e.g. P2, P3) will subsequently be evaluated to determine if the new possible spacing error rectangle is totally covered by other metal in the same fashion.

The process for determining whether a non-diagonal possible spacing errors is an actual error is discussed above. For diagonal possible spacing errors different techniques are utilized and are discussed below with respect to Figures 8-10.

More specifically, Figure 8 illustrates a diagonal possible spacing error P1 between metal shapes M1 and M2. The diagonal measure of rectangle P1 is less than the minimum spacing constraint of the design rules and no other metal shapes in the design intersect the P1 rectangle. Therefore, the possible error

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invention works much faster because the complexity and number of the rectangles analyzed is reduced.

While the overall methodology of the invention is described above, the invention can be embodied in any number of different types of systems and executed in any number of different ways, as would be known by one ordinarily skilled in the art. For example, as illustrated in Figure 11, a typical hardware configuration of an information handling/computer system in accordance with the invention preferably has at least one processor or central processing unit (CPU) 11. The CPUs 11 are interconnected via a system bus 12 to a random access memory (RAM) 14, read-only memory (ROM) 16, input/output (I/O) adapter 18 (for connecting peripheral devices such as disk units 21 and tape drives 40 to the bus 12), user interface adapter 22 (for connecting a keyboard 24, mouse 26, speaker 28, microphone 32, and/or other user interface device to the bus 12), communication adapter 34 (for connecting an information handling system to a data processing network), and display adapter 36 (for connecting the bus 12 to a display device 38).

A flowchart of the foregoing embodiment of the invention is shown in Figure 12. More specifically, in block 10 the metal and space rectangles are formed for all metal shapes within the net, as discussed above. In block 20 the rectangles are compared using a plane sweep algorithm to determine which metal and space rectangles are intersecting. From this information, block 30 creates the initial list of possible spacing errors.

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computer program, could determine whether a potential spacing error exists and whether the possible spacing error is diagonal or non-diagonal. An example of the pseudo-code for such a software program follows.

```

5  activeList = empty
   netPartList = empty
   possibleErrorList = empty
   diagonalPossibleErrorList = empty

   For each net part
       add space rectangle keyed by it's low x
10      coordinate to netPartList
       add space rectangle keyed by it's high x
       coordinate to netPartList
   endFor

   Sort netPartList

15  // Iterate through netPartList
   while (sortedNetPart = getNext(netPartList))
       if (sortedNetPart key is low x)
           For every activeListNetPart in activeList
*See NOTE
20             Compare(sortedNetPart, activeListNetPart)
           endFor
           add sortedNetPart to activeList
       else
           delete sortedNetPart from activeList
25  endwhile

   Compare(netPart1, netPart2)
       if netPart1 and netPart2 metal rectangles do not
           intersect
           if netPart1 space rectangle intersects
30             netPart2 metal rectangle
               OR
           netPart2 space rectangle intersects netPart1
           metal rectangle
           Compute distance between metal shapes
35             if distance < spacing requirement
                 Add intersection of the two space
                 rectangles to either
                 possibleErrorList or
                 diagonalPossibleErrorList

```

```

endIf
endIf
endIf
endCompare

```

5 Note: Rather than a simple iteration of the activeList
in the loop above, many other possible data structure
implementations could be applied to the activeList and
the compare stage of the activeList processing. A
10 radix search tree or priority search tree could improve
performance if the number of net parts was very large.

Additionally, a computer program, or a portion of a computer program,
could evaluate a possible non-diagonal spacing error to determine whether a
possible non-diagonal error is actually a true error to be reported to the user.

15 More specifically, such a computer program or portion of a computer
program could determine if a possible spacing error rectangle is covered by other
metal in the design. The invention could remove a spacing error from the list of
possible errors upon determining the possible spacing error rectangle is entirely
covered by metal. Upon determining the possible spacing error rectangle is
partially covered by metal, the invention could calculate new possible spacing
20 error rectangles by subtracting the covered area from the initial possible spacing
error rectangle and could replace the original possible spacing error with the
newly created possible spacing errors. An example of the pseudo-code for such a
software program follows.

```

25 // Iterate through net parts, stopping if
// possibleErrorList is empty
For each netPart and possibleErrorList is not empty

```

```

// Iterate through possibleErrorList
while (possibleError = getNext(possibleErrorList))
    If possibleError was not created from this
    netPart
5       Intersect the netPart metal rectangle
        with the possibleError rectangle
        If the intersection rectangle is more
        than a line
        Subtract the intersection rectangle
10       area from the possibleError
        rectangle, possibly
        creating/deleting
        possibleErrorList elements
        endIf
15     endIf
    endWhile
endFor

// Any remaining possibleErrorList elements are errors
while (possibleError = getNext (possibleErrorList))
20     Report possibleError rectangle as an error
endWhile

```

Additionally, a computer program, or a portion of a computer program, could evaluate a possible diagonal error to determine whether a possible diagonal error is actually a true error to be reported to the user.

25 More specifically, such a computer program or a portion of a computer program could evaluate whether additional metals exists which collectively intersect the edges of the diagonal possible spacing error rectangle and whether those edge intersections indicate a metal connection between the original metal rectangles comprising the possible spacing error.

The invention could compare the diagonal possible spacing error rectangle edges to the metal rectangles of all other net parts. As metal rectangles are found which intersect the edges, the invention could split, shorten or remove the edges of the possible error rectangle at the area of the intersection of the possible error rectangle and the metal rectangle. The invention could then evaluate the remaining edges to determine if two adjacent edges connecting the original metal shapes comprising the diagonal possible spacing error have been removed by this process and, if so, could remove the possible spacing error from the list of possible spacing errors. This situation is similar to that shown in Figure 9.

However, if the edges of the possible diagonal error rectangle which have been removed do not connect the original metal shapes comprising the error, the possible spacing error would be considered a true spacing violation. This is similar to the situation shown in Figure 10. An example of the pseudo-code for such a software program follows.

```
// Iterate through diagPossibleErrorList
while (possibleError = getNext(diagPossibleErrorList)

    if possibleError rectangle is a line

        create one edge

        // Iterate though net parts, stopping if
        // edge is null
        For each netPart and edge != NULL
            process_this_edge(netPart, edge)
        endfor

        if (edge == NULL) // Edge totally removed
            remove possibleError from
            diagPossibleErrorList
        endif
```

```

else // possibleError is a rectangle

    create four edges (east, west, north, south)
    still_error = true

    // Iterate through net parts stopping if
    // no longer an error
    5 For each netPart and still_error
        process_this_edge(netPart, edge_east)
        process_this_edge(netPart, edge_west)
        process_this_edge(netPart, edge_north)
    10 process_this_edge(netPart, edge_south)
    endfor

    // Have the appropriate edges been removed?
    if ((metal shapes are at the NE and SW
    15 corners of possibleError rectangle) AND
        ((edge_east == NULL) &&
        (edge_south == NULL)) OR
        ((edge_west == NULL) &&
    20 (edge_north == NULL)))
        still_error = false
    endif

    if ((metal shapes are at the NW and SE
    corners of possibleError rectangle) AND
    25 ((edge_west == NULL) &&
        (edge_south == NULL)) OR
        ((edge_east == NULL) &&
        (edge_north == NULL)))
        still_error = false
    endif

    30 if ( ! still_error )
        remove possibleError from
        diagPossibleErrorList
    endif

    35 endif
endwhile

// Any remaining diagPossibleErrorList elements are
// errors
while (possibleError = getNext(diagPossibleErrorList))
    Report possible Error rectangle as an error
40 endwhile

```

```

process_this_edge(netPart, edge_list)

    // Iterate through partial edges associated with
    // this edge
    while (partial_edge = getNext(edge_list))
5       if netPart metal rectangle intersects
           partial_edge
               if intersection is entire partial edge
                   remove partial_edge from edge_list
               else
10                  modify partial edge to reflect
                     remaining edge after intersection
                     possibly splitting into two
                     partial edges
               endif
           endif
15       endwhile
    endwhile

endProcess_this_edge

```

Therefore, the invention is superior to conventional systems because the
 invention allows same net spacing errors to be recognized during physical design
 prior to Design Rules Check. The software supporting the invention performs
 orders of magnitude faster than the Design Rules Check solution. As such, the
 invention dramatically decreases the turn-around time of physical design, providing
 a fast solution which is available prior to final layout release.

The invention is general in nature and can be applied to any application
 which can represent the application data as a set of connected rectangles and a set
 of spacing constraints. For example, any application which architects nets, such as
 mazes for mice or other objects to pass through, might wish to ensure the spacing
 in the structure would meet a minimum requirement so that the mice or other
 objects do not get stuck.

While the invention has been described in terms of preferred embodiments, those skilled in the art will recognize that the invention can be practiced with modification within the spirit and scope of the appended claims.

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